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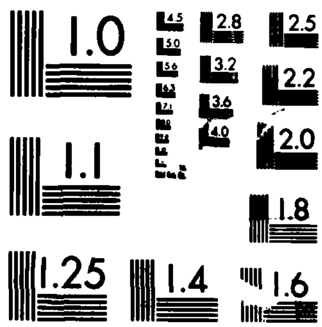
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FOREIGN TECHNOLOGY DIVISION

CONTROL OF LAMINAR FLOW AROUND OF THE WING IN FREE- AIR CONDITIONS

by

V.B. Zozulya, O.R. Cheranovskiy

PARTIALLY EDITED MACHINE TRANSLATION

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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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Page 3.

Control of laminar flow around of the wing in free- air conditions.

V. B. Zozulya, O. R. Cheranovskiy.
(Kharkov aviation institute).

Realization of control of laminar flow (ULO) for purpose of decrease of profile drag of wing will allow contemporary aviation equipment to complete considerable qualitative jump.

However, although from point of view of aerodynamics in this question relative clarity is achieved/reached, to speak about embodiment ULO in real wing constructions still early. In this question it is sufficient the unresolved fundamental questions for the aerodynamicists, designers, material-strength engineers and technologists. Systematic studies on the effect on the effectiveness of the suction of such important factors as atmospheric turbulence, strain of the permeable surface in the loading, vibration of construction/design, acoustical effects, etc are not conducted. Nevertheless each of these factors can introduce essential corrections. The effect of the initial turbulence of flow on the distribution of the speed of suction from the boundary layer of the penetrated plate with the ideally smooth surface is examined in work [2]. However, it is known that the initial turbulence of the atmosphere considerably less than values corrected to [2] comprises $\varepsilon=0.01\%$ [3]. As the investigations, carried out by Schubauer and Skramstad, showed, [5] with the sufficiently low turbulence level (order 0.08%) there is so-called upper critical Reynolds number. Therefore is of interest the experimental confirmation of this fact under the conditions of free atmosphere, and also the explanation of the minimally necessary suction intensity under such conditions. The decrease of initial turbulence in comparison with the value of turbulence in the duct by an order must lead to the noticeable increase in the extent of laminar section, which, however, under the conditions of the atmosphere must be limited by the value of upper critical Reynolds number (for plate $Re^{**}=1250$ [4]). In connection with this the value of suction intensity, necessary for the laminar flow, can be lowered approximately doubly in comparison with the values of intensity, obtained in the duct when $\varepsilon=0.2\%$.

(1) Номер щели	(2) Коэффициент расхода $c_{qi} \times 10^4$		
	(3) полученный в аэродинамической трубе, x_t=0,8 в	(4) рассчитанный по [2], x_t=0,8 в	(5) замеренный в полете, x_t=0,8в
1	—	—	—
2	0,5	—	0,3
3	0,2	—	0,37
4	0,47	0,44	0,38
5	0,49	1,03	0,37
6	0,52	0,61	0,39
7	0,51	1,21	0,33
$c_Q = \Sigma c_{qi}$	2,69	3,29	2,14

Key: (1). Number of slot. (2). Coefficient of expenditure/consumption .... (3). obtained in wind tunnel, ... (4). designed on [2], ... (5). measured in flight, ...

Page 4.

Investigations are conducted on wing of pilotless flying laboratory. Wing profile in the slotted section being investigated is carried out according to technical specifications to the models of laminar-flows profile for the blasting. Wobble atmospheric turbulences are estimated along the length of the laminar section of boundary layer without the suction and in the required suction intensity for obtaining the calculated extent of laminar boundary layer. The results of calculations and blasting in the wind tunnel (when ε=0,2%) are compared with the results of the investigations, carried out in flight.

It is known that lamination of boundary layer by suction of liquid through permeable surface can be carried out under condition of observing equality of local Reynolds number to his critical value at transition point, which depends on initial turbulence of flow and roughness of body surface.

Utilizing calculation procedure, for flight conditions [2], on which are conducted measurements of parameters of boundary layer with suction, we determine coefficient of expenditure/consumption for each slot. Initial data for the calculation: the speed of flow U_∞=40 m/s, the experimental chord diagram of profile pressure distribution for the angle of attack of α=6°. The results of experiments and calculation are given in the table. The wing of pilotless laboratory (Fig. 1) has the following parameters: chord - 0,8 m; the span of wing - 4 m; profile/airfoil laminar c=18%. Right console has the slotted section of the upper panel with a width of 0.70 m. In the slotted section the profile/airfoil possesses the following special features: the roughness of the surface approximately 2 μ; undulation is less than 0.1 mm on the basis 100 mm; departure from the theoretical contour is less than 1% maximum profile thickness.

Wing is composite construction with plastic sandwich skin (thickness of 4-10 mm) and duralumin machine tools. The location of slots along the profile/airfoil is predetermined, the width of slots is accepted by the constant of 0.2 mm. Slots (50 mm) are alternated with the cross connections of skin/sheathing (10 mm) and staggered. The considerable thickness of skin/sheathing makes it possible to fulfill air-collecting with the diameter of 4 mm and air-collecting wells within the filler.

Uniformity of suction along slot is provided by variable space of air-collecting wells, which have diameter of 2 mm. Expenditures/consumptions on the slots are regulated by introduction to each channel of the throttling diaphragms. Suction is realized by the compressor, established/installed in the wing and which has drive from the electric motor, which is supplied from the onboard storage battery/accumulator. The path of exhausted air is the following: slot, that air-discharges well, slotted channel, Venturi tube, the throttling diaphragm, receiver, compressor, exhaust pipe (Fig. 2).

Fig. 1. Wing of flying laboratory.

Page 5.

The slotted section of wing has the catch drains formed in the filler of sandwich skin with a diameter of 2 mm.

Measurements, carried out in experimental section of wing, should be divided into three groups: 1) measurement of structure of incident flow (turbulence level); 2) measurement of kinematic parameters (angles of attack and slip, flight speed); 3) measurements, connected with manifestation of effect of suction of boundary layer (profile drag, length of laminar section of flow, flow rates of exhausted air through slots, distribution of pressures in slotted channels).

Mechanism of laminar-turbulent transition with turbulence level of flow $\epsilon \leq 0.08\%$, probably, in principle it differs from mechanism of transition with $\epsilon > 0.1$- 0.15%. In work [5] it is shown that with small turbulence levels the transition is the result of the self-generating oscillations/vibrations under the effect of either the heterogeneities of flow or surface roughness. On the basis of the results of these investigations it is possible to only assume, that turbulence level not omni-controlled factor that, probably, the investigation of the frequency spectrum of the turbulent pulsations and their energy content in the atmosphere they will aid in the solution of a question about the required suction intensity of boundary layer.

At flying laboratory turbulence level of atmosphere is measured by scavening method of sphere [3], which to rod is fastened/strengthened on forward fuselage. Velocity head and feed pressure of sphere are recorded by potentiometric pickups with the recording to the loop oscillograph.

Kinematic parameters (angles of attack and slips, flight speed, etc.) are measured by standard potentiometric pickups with recording of readings/indications to plank of onboard loop oscillograph.

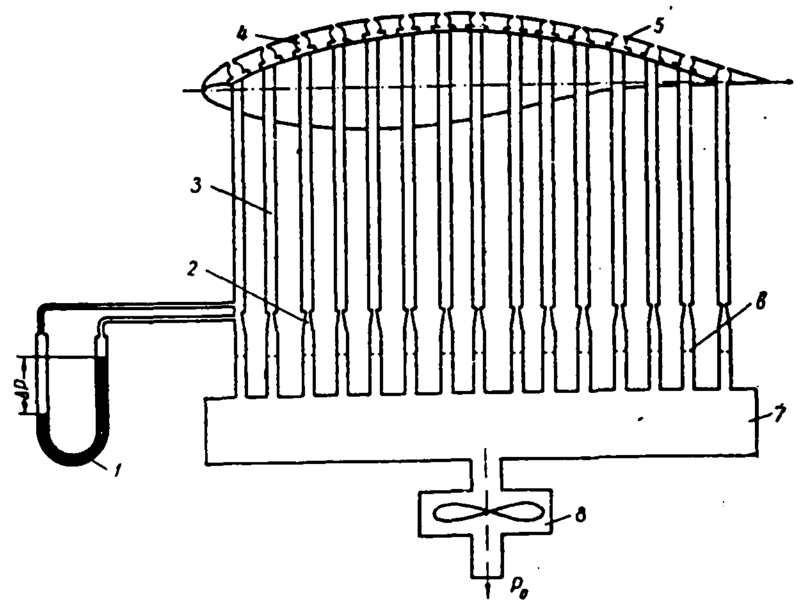


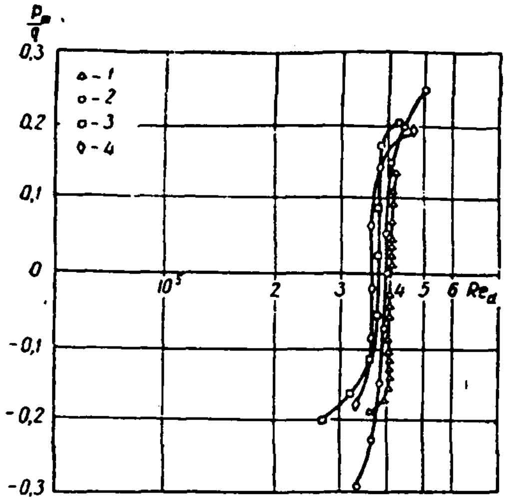
Fig. 2. Schematic of boundary-layer bleed: 1 - manometer, 2 - Venturi tube, 3 and 4 - air-discharge channels; 5 - slot, 6 - throttling washers, 7 - receiver, 8 - exhaust pump.

Page 6.

Losses of head in the wake in the measurement of profile drag by the method of pulses, the drops/jumps pressure on the Venturi tubes in the suction system, pressure on the profile/airfoil at drainage points, pressure in the subslotted channels are recorded by one induction sensor of the type DMI - 0.1, which is connected to the graduated points by alternately pneumatic commutator with switching rate of 50 points of. Recording is conducted on the film of loop oscillograph.

Recording laminar-turbulent transition on profile/airfoil is realized by coordinate spacer apparatus [1], which is hot-wire anemometer automatically moving along profile/airfoil at constant distance from surface, pulsating component of signal of hot-wire anemometer is recorded to plank of loop oscillograph. According to the character of pulsations the zone of the transition of boundary layer into the turbulent state is defined.

Results of experiments, carried out in flight.



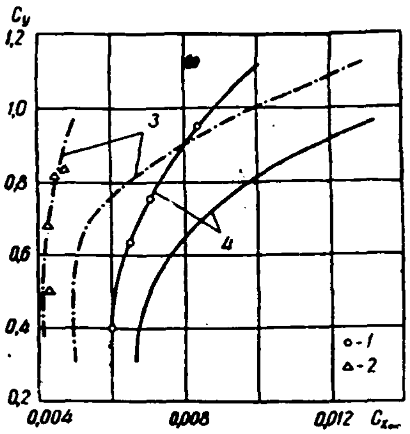


Fig. 3.

Fig. 4.

Fig. 3. Dependence of atmospheric turbulence on critical Reynolds number of sphere: 1 - wind velocity 0.5 m/s, height/altitude of 100 m, diameter of sphere 200 mm, 2 - wind velocity 0.5-0.7 m/s, height/altitude of 100 m, diameter of sphere 200 mm, 3 - wind velocity 6 m/s, height/altitude of 600 mm, diameter of sphere 150 mm, 4 - wind velocity 10 m/s, height/altitude of 500 m, diameter of sphere 150 mm.

Fig. 4. Dependence of polar of profile/airfoil on flow turbulence and suction $1-c_Q=0$, $2-c_Q=0.00033$ (values, obtained in flight); $3-c_Q=0$; $4-c_Q$ in acc. with $c_{x\min}$ (values, obtained in the duct).

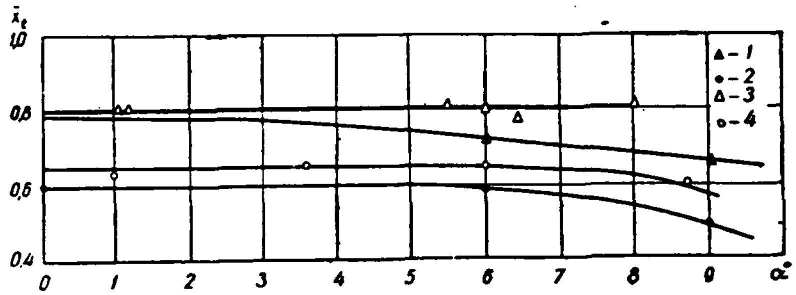


Fig. 5. Position of transition point on upper wing surface, found at investigation in duct $(1 - c_Q \neq 0,\ 2 - c_Q = 0)$ and in flight $(3 - c_Q = 0{,}00033,\ 4 - c_Q = 0)$.

Page 7.

With blasting of sphere in flight at flying laboratory is obtained Reynolds number of sphere $Re_d = 385\,000 \div 401\,000$, which corresponds to turbulence level of flow $\varepsilon \approx 0{,}03\%$. Flights were accomplished in the morning hours, almost in the complete absence of the wind and updraft. Measurements are produced at the height/altitude to 50 m (Fig. 3).

In switched on system of suction under the conditions of gliding/planning with assigned intensity of suction along chord laminar-turbulent transition occurs to 80% of chord, and profile drag decreases from $C_x = 0{,}0070$ to $C_x = 0{,}0042$. The comparison of the results, obtained in flight and in the duct (Fig. 4 and 5), detects a certain difference, which can be explained by the smaller turbulence level of flow, under the conditions for the free flight of the circumfluent wing.

Calculation of intensity of suction, in view of absence it is sufficient dependence $Re_{кр}^{**}$ checked on ϵ with $\epsilon<0.2\%$, it gives value c_Q, overstated in comparison with c_Q, obtained in duct when $\epsilon=0,2\%$. The reason for disagreement, obviously, is the inadequacy of the diagram of junction accepted with the very slight disturbances, which exist under the conditions for free flight.

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